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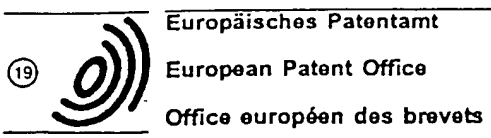
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(54) Method for altering patterns provided at a surface of a carrier and apparatus for carrying it out.

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## Description

The invention relates to a method for altering patterns provided at a surface of a carrier by means of an ion beam originating from a liquid metal ion source, whereby for removing and/or depositing material at the surface, the ion beam is directed onto the surface.

Such a method is disclosed in Patent Application WO 86/02774. By a method described in said application material is deposited on the carrier by an ion beam from a supplied gas flow. Disadvantages of this method are that the supplied gas which can only very partly be ionised, pollutes the apparatus and that the accuracy of material deposition is restricted by scattering of the ions of the gas flow. This latter is particularly unfavourable for the use, for example, in repair or adaptations of chips or more in particular of masks for chip production. An accurate, sharply bounded material deposition is of decisive importance. Corresponding requirements, though they may be less stringent, are also imposed, for example, for repair or adaptation of gratings to be used, for example, for optical or X-rays spectroscopy, as described in GB 1,384,281. In both examples patterns are used with structures of at most, for example, approximately 1  $\mu\text{m}$  and for a good finishing thereof an active ion spot diameter of at most a few tenths of a  $\mu\text{m}$  is necessary. In particular for masks to be used in electron beam apparatuses or in X-ray apparatuses, it is difficult to achieve sufficient definition in material deposition from a gas flow because, due to the required radiation absorption of the material, the gas flow must comprise atoms with a comparatively large mass. The scattering will become larger due to the mass ratio which is more unfavourable with respect to the source ions.

For a finishing apparatus for the said patterns it is favourable that it is suitable for both material removal and for material deposition with a transverse dimension of at most approximately 0.1  $\mu\text{m}$  for the writing ion spot, that material which is also useful for subsequent processing with X-rays and electrons can be deposited, that material can be rapidly removed and be deposited, and that a good location control during the treatment is possible.

It is the object of the invention to remove the said disadvantages of existing methods and apparatuses and to satisfy the requirements to be imposed to a considerable extent and for that purpose a method for altering patterns is according to the invention characterized in that for material deposition metal is transported from the ion source and deposited on the surface by the ion beam.

Because in a method according to the invention a gas flow for material deposition is not used, both pollution of the ion beam apparatus and scattering of the ion beam are avoided.

In a preferred embodiment the ion beam current for material removal can be adjusted at at most

approximately 10  $\mu\text{A}$  and at at least approximately 30  $\mu\text{A}$  for material deposition. Energy up to approximately 10 keV may be used for material removal and up to many tens of keV for material deposition. For an accurate positioning of the ion beam on the surface and for an unambiguous apparatus design, it is favourable to work in both modes with at least approximately equal ion energy.

An apparatus for altering patterns provided at a surface is according to the invention characterized in that the apparatus is equipped only with electrostatically operating ion optical elements for focussing and deflection of the ion beam. As a result of this, dispersion of ions or other positively charged particles of equal energy is avoided.

If on the contrary it is desired to separate mutual different charge carriers, magnetic deflection systems may be used in which for the removal of only noncharged particles without dispersion of the charged particles two mutually compensating magnetic deflection devices or a combination of magnetic and electrostatic fields may be used. One of these deflection devices may also serve as a beam interrupter.

In a further embodiment the ion source is a liquid gold source with which hence gold is deposited which is favourable in particular as a material which is sparingly transparent for electrons and X-rays.

In a further embodiment, an electron source directed to the object is incorporated for the neutralisation of detrimental local charge optionally occurring on the carrier during the treatment. An electron source which is readily directed and focused on the object may also be used for location indication but preferably the ion beam itself is used for this purpose. For the detection of a location signal the apparatus may comprise a detector which is suitable for that purpose.

A few preferred embodiments according to the invention will now be described in greater detail hereinafter with reference to the accompanying drawing. The sole Figure of the drawing shows diagrammatically an apparatus according to the invention.

An apparatus as shown diagrammatically in the drawing comprises in a housing 1 to be evacuated an ion source 2 having an emission point 4 conventionally operated at high voltage, an extraction electrode 6, a second electrode 8, a high voltage electrode 9, a beam focusing device 10, a beam deflection device 12, a beam deflection device 14 and an object table 16 having thereon an object 18 to be worked. An object moving system 17 for, for example, moving the object in X-Y coordinates is attached to the object table. An electron source 20 and a detector 22 are furthermore incorporated in the housing and are directed on the object. The ion source in this case is a liquid metal ion source (LMIS) and comprises in general a sharp emission point to be heated on which a layer of, for example, gold, aluminium, silicon, boron, gallium

or another useful metal or a combination of material has been provided in which the material to be used, which in this case is not necessarily a metal form, is incorporated, for example, AuSi, Pt Nib, etc. During operation of the apparatus the layer of material is in the liquid phase. The current strength of the ion beam may be varied by means of the extraction electrode 6 between, for example, a few  $\mu\text{A}$  and 150  $\mu\text{A}$  or more. A potential to be applied to the high voltage electrode 9 which conventionally is at least substantially equal to the potential of the object determines the energy of the ions in an ion beam 25 to be emitted. The ion beam can be focused in a small working spot 26 by means of the focusing device. A surface 26 of the object 18 to be worked can be scanned by means of the beam deflection device 14 in a grating or a vector scanning method. The beam deflection device is necessary only when it is desired to purify the ion beam 25 of neutral particles, comparatively heavy charged particles, multiple ions, and the like, optionally occurring in the beam. The ion beam is first, for example, deflected away from an optical system axis 27 and is then made to coincide again with said axis. For the mode for removal of material, usually termed sputtering, in which the ion source is adjusted at a comparatively low current value, a good homogeneous ion beam is emitted. For particle selection the deflection device then is superfluous. This may also be used as a beam interrupter, for example, by switching on and off a first deflection element 29 in which the beam impinges on an asymmetrically placed diaphragm 30 or when the second deflection element 31 is switched off, the beam impinging on a diaphragm 32. When this form of beam blanking is not desired, for example, because the source has to be switched on and off, the diaphragm 30 is removed from the main axis of the system. Undesired material may be removed from a carrier surface by means of such a low current ion beam. For example, for that purpose a mask may be controlled for said defects in a separate apparatus designed for that purpose or by means, for example, of a focused electron source 20 and detector 22 adapted thereto or by means of a rapidly scanning ion beam in the finishing apparatus itself. An image of a pattern may be formed, for example, via a signal processing device 34 and be stored and displayed in an image recording display device 36. The ion source may then be controlled with an object with coordinated locations to be treated and associated with a central control device 38 for which purpose the relevant components of the apparatus influencing the ion beam are connected to the central control device. Potential excursions, if any, generated by the ion beam at the carrier surface may be neutralised by means of the electron gun 20. For location of the instantaneous position of the ion beam during processing of the carrier surface it is favourable to use a signal created at the area by the ion beam itself. Where

this meets with difficulties, location can also be realised by means of a synchronously scanning electron beam of the electron gun 20 now focused on the object.

For material deposition purposes an ion beam is used with which more material is deposited than is sputtered away. For a more rapid deposition the ion beam current may be increased in which, for example, more and more material is displaced between approximately 25 and 75  $\mu\text{A}$  and in which the mass transport increases more rapidly than the current strength. The more since it is suggested that charged clusters of material are then also formed, material must consequently be taken along in a form other than ions. It is assumed that in particular charged particles of material but also non-charged particles of material occur in the beam. When the current strength becomes comparatively high, particles of material may occur which are too large to be able to satisfy the desired resolving power. Said undesired particles can then be sieved out exactly by the deviating charge-mass ratio, by means of the deflection device and an intensive beam of sufficiently small particles may be used. In order to neutralise the dispersion occurring in such a deflection, the deflection system may be given a double construction. In addition to the advantage that the gas supply in the apparatus is avoided, the apparatus has the great advantage that both types of defects, namely the presence of material where it should not be and the absence of material where it should be, can be restored or replenished in one apparatus. Because in the restorage of clear defects, so locations where no or too little material is erroneously present, material is really added and a scattering surface is not formed at the area as, for example, is done for optical masks, the apparatus, equipped with an ion source suitable for that purpose, is also suitable for masks for, for example, X-ray or electron lithography. Furthermore, a wide adjusting range is possible between on the one hand a shape edge resolution for fine structures in the patterns with an ion beam current up to, for example, approximately 100 to 150  $\mu\text{A}$ , and on the other hand a very rapid working of coarser structures with current intensities up to, for example, 500  $\mu\text{A}$ . While maintaining a rapid working, a high beam current and an active particle selection system in the apparatus may be used. Particles having, for example, a mass above a value to be fixed may then be removed from the beam. Because it is always source material, the particle mass and the particle dimensions are directly correlated. When no dispersion in the apparatus is desired, all the ion optical elements are constructed to be electrostatic. Under the real assumption that the energy of all charged particles is mutually at least substantially equal, no dispersion consequently occurs upon deflection and neutral particles can yet be removed. An argument in favour of selection may be,

in addition to the removal of optionally too large and neutral particles, that a particle beam is selected having such an equal scanning influencing by deflection fields other than the electrostatic fields that the occurrence of, for example, spot increase or deformation by increasing scanning angle is avoided.

## Claims

1. Method for altering patterns provided at a surface of a carrier by means of an ion beam originating from a liquid metal ion source, whereby for removing and/or depositing material at the surface, the ion beam is directed onto the surface, characterized in that for material deposition a high ion beam current is chosen, whereby metal is transported from the ion source and deposited on the surface by the ion beam, and that for removal a low ion beam current is chosen.
2. Method as claimed in Claim 1, characterized in that an ion beam current of approximately 30 to 150  $\mu\text{A}$  is used for material deposition.
3. Method as claimed in Claim 1 or 2, characterized in that an ion beam energy is substantially equal for the material removal and the material deposition.
4. An apparatus for altering patterns provided at a surface according to method as claimed in Claim 1, 2 or 3, characterized in that the apparatus is equipped only with electrostatically operating ion optical elements for focussing and deflection of the ion beam.
5. An apparatus as claimed in Claim 4, characterized in that it is equipped with a deflection system operating selectively on chargemass ratio of charged particles in the ion beam.
6. In apparatus as claimed in Claim 5, characterized in that it comprises a second deflection element compensating for an energy dispersion of a first deflection element.
7. An apparatus as claimed in Claims 4, 5 or 6, characterized in that for the neutralisation of a potential excursion at the carrier surface to be built up by the ion beam an electron source to be directed thereto is incorporated.
8. An apparatus as claimed in any of the Claims 4 to 7, characterized in that a detection system directed laterally on the surface is incorporated for the position control of a target of the ion beam on the carrier surface.
9. An apparatus as claimed in any of the Claims 4 to 8, characterized in that for the position control of a target of the ion beam on the carrier surface it is provided with an SEM detection system directed laterally on the surface.
10. An apparatus as claimed in any of the Claims 4 to 9, characterized in that the ion source is a liquid gold ion source
11. An apparatus as claimed in any of the Claims

4 to 10, characterized in that an element of a double beam deflection system therein can be switched as a beam interrupter.

## Ansprüche

1. Verfahren zum Ändern von Mustern auf einer Trägeroberfläche mit Hilfe eines Ionenstrahls aus einer Flüssigmetall-Ionenquelle, wobei zum Entfernen und/oder Niederschlagen von Werkstoff auf der Oberfläche das Ionenbündel auf die Oberfläche gerichtet wird, dadurch gekennzeichnet, daß zum Niederschlagen von Werkstoff ein großer Ionenbündelstrom gewählt wird, wobei aus der Ionenquelle Metall abgetragen und durch das Ionenbündel auf die Oberfläche niedergeschlagen wird, und daß zum Entfernen ein niedriger Ionenbündelstrom gewählt wird.
2. Verfahren nach Anspruch 1, dadurch gekennzeichnet, daß zum Werkstoffniederschlagen ein Ionenbündelstrom von etwa 30 bis 150  $\mu\text{A}$  benutzt wird.
3. Verfahren nach Anspruch 1 oder 2, dadurch gekennzeichnet, daß eine Ionenbündelenergiemenge sowohl zum Abtragen als auch zum Niederschlagen von Werkstoff im wesentlichen gleich ist.
4. Gerät zum Ändern von Mustern auf einer Oberfläche mit einem Verfahren nach Anspruch 1, 2 oder 3, dadurch gekennzeichnet, daß zum Fokussieren und Ablenken des Ionenbündels das Gerät nur mit elektrostatisch arbeitenden ionenoptischen Elementen ausgerüstet ist.
5. Gerät nach Anspruch 4, dadurch gekennzeichnet, daß es mit einem Ablensystem versehen ist, das selektiv mit spezifischer Ladung von Ladungsteilchen im Ionenbündel arbeitet.
6. Gerät nach Anspruch 5, dadurch gekennzeichnet, daß es ein zweites Ablenkelement enthält, das eine Energiestreuung eines ersten Ablenkelements ausgleicht.
7. Gerät nach Anspruch 4, 5 oder 6, dadurch gekennzeichnet, daß zum Neutralisieren einer vom Ionenbündel aufgebauten Potentialabweichung auf der Trägeroberfläche eine darauf auszurichtende Elektronenquelle aufgenommen ist.
8. Gerät nach einem der Ansprüche 4 bis 7, dadurch gekennzeichnet, daß zur Positionssteuerung eines Targets des Ionenbündels auf der Trägeroberfläche ein seitlich auf die Oberfläche gerichtetes Detektorsystem aufgenommen ist.
9. Gerät nach einem der Ansprüche 4 bis 8, dadurch gekennzeichnet, daß zur Positionssteuerung eines Targets des Ionenbündels auf der Trägeroberfläche das Gerät mit einem seitlich auf die Oberfläche gerichteten REM-Detektorsystem ausgerüstet ist.
10. Gerät nach einem der Ansprüche 4 bis 9, dadurch gekennzeichnet, daß die Ionenquelle eine Flüssiggold-Ionenquelle ist.

11. Gerät nach einem der Ansprüche 4 bis 10, dadurch gekennzeichnet, daß ein Element eines Doppelbündel-Ablenksystems darin als Bündelunterbrecher schaltbar ist.

### Revendications

1. Procédé pour la modification de motifs prévus sur une surface d'un support au moyen d'un faisceau ionique provenant d'une source d'ions à métal liquide, selon lequel pour enlever et/ou déposer de la matière sur la surface, on dirige le faisceau ionique vers la surface, caractérisé en ce que, en vue du dépôt de matière, un courant de faisceau ionique élevé est choisi, de sorte que du métal est transporté à partir de la source d'ions et est déposé sur la surface par le faisceau ionique et que, en vue de l'enlèvement de matière, un courant de faisceau ionique faible est choisi.

2. Procédé suivant la revendication 1, caractérisé en ce qu'un courant de faisceau ionique d'environ 30 à 150  $\mu\text{A}$  est utilisé pour le dépôt de matière.

3. Procédé suivant la revendication 1 ou 2, caractérisé en ce qu'une énergie de faisceau ionique est en substance égale pour l'enlèvement et pour le dépôt de matière.

4. Appareil pour la modification de motifs prévus sur une surface à l'aide d'un procédé suivant la revendication 1, 2 ou 3, caractérisé en ce qu'il n'est équipé que d'éléments optiques pour ions à fonctionnement électrostatique pour la focalisation et la déviation du faisceau ionique.

5. Appareil suivant la revendication 4, caractérisé en ce qu'il est équipé d'un système de déviation fonctionnant sélectivement sur base du rapport charge-masse des particules chargées dans le faisceau ionique.

6. Appareil suivant la revendication 5, caractérisé en ce qu'il comprend un second élément de déviation compensant une dispersion d'énergie d'un premier élément de déviation.

7. Appareil suivant la revendication 4, 5 ou 6, caractérisé en ce que, pour la neutralisation d'une excursion de potentiel au niveau de la surface du support destinée à être formée par le faisceau ionique, une source d'électrons dirigée vers cette surface est prévue.

8. Appareil suivant l'une quelconque des revendications 4 à 7, caractérisé en ce qu'un système de détection dirigé latéralement sur la surface est prévu pour commander la position d'une cible du faisceau ionique sur la surface du support.

9. Appareil suivant l'une quelconque des revendications 4 à 8, caractérisé en ce qu'il est pourvu, pour la commande de la position d'une cible du faisceau ionique sur la surface du support, d'un système de détection SEM dirigé latéralement sur la surface.

10. Appareil suivant l'une quelconque des revendications 4 à 9, caractérisé en ce que la source d'ions est une source d'ions à or liquide.

11. Appareil suivant l'une quelconque des revendications 4 à 10, caractérisé en ce qu'un élément d'un double système de déviation de faisceau qui y est incorporé peut être commuté comme un interrupteur de faisceau.

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